Safe Flight 21

Initial Report of the Safe Flight 21 Cost Benefit Subgroup Volume 2

May 2000

LIST OF APPENDICES

INSERT APPENDIX C (Technical Baseline and Cost Baseline for Limited Deployment Briefing)

APPENDIX D

INTRODUCTION TO BENEFITS

Phase 1 Benefits assessment of Safe Flight 21 technologies focused on quantifying a sample of enhancements for Limited Deployment in the Ohio River Valley and the state of Alaska. These efforts yielded initial figures to support the FAA FY02 budget estimates.

The following set of briefings includes a detailed description of data collection efforts, analysis methodology, and results for each enhancement analyzed.

INSERT ENHANCEMENT BRIEFINGS

APPENDIX E

SUMMARY OF MASTER PLAN

SAFE FLIGHT 21 OPERATIONAL ENHANCEMENTS AND APPLICATIONS

Overview

The RTCA Select Committee was very explicit, at a high level, in their *Roadmap* document concerning the scope of evaluations that they expected in order to advance the modernization of CNS in the NAS. The Safe Flight 21 Steering Group, comprising the stakeholders interested in these enhancements, have come to a consensus on the applications that will be initially developed and evaluated to show the benefits and reduce the risk of implementing the enhancements.

The remainder of this section reiterates the nine enhancements from the Roadmap and breaks out the applications that will be evaluated. Since this is an evolving plan, a mapping to applications that have been considered in previous versions of this plan is made at the end of the section. There are applications similar to these defined, or at least alluded to, in the ADS-B MASPS, the ATS Concept of Operations for the National Airspace System in 2005, and the Government/Industry Operational Concept for the Evolution of Free Flight. The mapping at the end of this section shows those connections. The applications currently planned for evaluation by Safe Flight 21 are summarized in Table 3-1. The application description that follow include all phases within the applications.

Table 1-1. Safe Flight 21 Applications

Enhancement		Ops Eval Fiscal Year	Application
Weather and Other Information to the Cockpit	1.1.1	00 (AK)	Initial FIS-B based on today's availability (NEXRAD graphics, METAR/SPECI, TAFs, SIGMETs, PIREPs, and sever weather forecast alerts)
	1.1.2	01 (AK)	Add products such as NOTAMs, lightning, icing, turbulence, real time SUA, and Volcanic ash
Cost Effective CFIT Avoidance	2.1	00 (AK)	Low cost terrain situational awareness
	2.2	01 (AK)	Increased access to terrain constrained low altitude airspace
Improved Terminal Operations in Low Visibility	3.1.1	99 (ORV)	Enhanced visual approaches (Visual acquisition with existing procedures, ADS-B only)
	3.1.2	00 (ORV)	Enhanced visual approaches (with new procedures using ADS-B only)
	3.1.3	01 (ORV)	Enhanced visual approaches (with new procedures using ADS-B and TIS-B)
	3.2.1	00 (ORV)	Approach spacing (for visual approaches)
	3.2.2	01 (ORV)	Approach spacing (for instrument approaches)
	3.4	00 (ORV)	Departure spacing/clearance (VMC in radar)
Enhanced See and Avoid	4.1.1	99 (ORV)	Enhanced visual acquisition of other traffic for see-and-avoid (using ADS-B only)
	4.1.2	01 (Both)	Enhanced visual acquisition of other traffic for see-and-avoid (ADS-B and TIS-B)
	4.2.1	00 (ORV)	Conflict detection
	4.2.2	02 (ORV)	Conflict resolution
Enhanced En Route Air-to-Air Operations	5.2.1	00 (AK)	Pilot situational awareness beyond visual range
Improved Surface Surveillance and Navigation for the Pilot	6.1.1	00 (Both)	Runway and final approach occupancy awareness (using ADS-B only)
	6.1.2	01 (ORV)	Runway and final approach occupancy awareness (using ADS-B and TIS-B)
	6.2	01 (Both)	Airport surface situational awareness
Enhanced Surface Surveillance for Controller	7.1	00 (ORV)	Enhance existing surface surveillance with ADS-B
	7.2	01 (ORV)	Surveillance coverage at airports without existing surface surveillance
ADS-B Surveillance in Non-Radar Airspace	8.1	00 (AK)	Center situational awareness with ADS-B
	8.2	00 (AK)	Radar-like services with ADS-B
	8.3	00 (AK)	Tower situational awareness beyond visual range
Establish ADS-B Separation Standards	9.1.1	00 (Both)	Radar augmentation with ADS-B to support mixed equipage in terminal airspace
	9.2.1	00 (Both)	Radar augmentation with ADS-B to support mixed equipage in en route airspace

(Note: Applications not evaluated in 1999 through 2002 are listed in Tables 3-3 and 3-4)

Enhancement 1: Weather and Other Information to the Cockpit

This enhancement will use the Flight Information System (FIS) to receive current and forecasted weather and flight information as well as other information. The enhanced weather products will be available to pilots and controllers, allowing them to share the same situational awareness. The information will be displayed textually and graphically to the pilot. The expected benefits are the following:

- Reduced flight times by skirting adverse weather
- Reduced flight times by exploiting available SUA
- Increased safety
- Reduced Flight Service Station workload
- More GA flight initiatives with weather information during flight
- Improvement in tactical planning for aircraft equipped with weather radar
- Improvement in tactical planning for aircraft equipped with icing and SUA graphics

App. 1.1.1 Initial FIS-B

This application will enhance pilot awareness of weather and airspace/facility status by incorporating broadcast flight information into cockpit multifunction displays. Initial (text only) products will include NEXRAD graphics, METAR and SPECI surface observations, TAFs and applicable amendments, SIGMETs and convective SIGMETs, AIRMETs, urgent and routine PIREPs, and Severe Weather Forecast Alerts.

App. 1.1.2 Additional FIS-B Products

This application will add additional exchange of aeronautical data that includes NOTAMs, lightning, icing, turbulence, real-time SUA, and volcanic ash.

1.2 Enhancement 2: Cost Effective CFIT Avoidance

There have been many fatal accidents involving controlled flight into terrain (CFIT) due to poor pilot situational awareness. This enhancement will increase the pilot's situational awareness by providing a cost/effective terrain and obstacle database and integrated display in the cockpit. The expected benefits are the following:

- Reduced CFIT accidents
- Decreased pilot workload
- Increased access to low altitude routes
- Increased capability to avoid hazardous weather conditions relating to certain altitude (e.g., icing)
- Increased ability to fly at lower altitude to avoid need for IFR at higher altitude

App. 2.1 Low Cost Terrain Situational Awareness

This application will enhance pilot awareness of terrain by using on-board databases, GPS navigation, and barometric altitude to generate moving terrain maps on cockpit multifunction displays. The initial capability color-codes vertical clearance to terrain, suitable for VFR operation.

App. 2.2 Increased Access To Terrain Constrained Low Altitude Airspace

This application adds capabilities including obstacle data to the on-board databases and provides alert functions. This increased situational awareness may facilitate lower altitude GPS routes or lower altitude random off-airway navigation for suitably equipped aircraft.

Enhancement 3: Improved Terminal Operations in Low Visibility

This enhancement will use ADS-B, CDTI and TIS-B during low visibility approach operations so that the crew will be better able to identify the aircraft to follow and accomplish approaches at lower minimums, thus maintaining VFR throughput longer. The crew will also be able to maintain better spacing during VFR and IFR approaches. The expected benefits are the following:

- Increased access to airports during marginal weather
- Reduced arrival delays
- Increased predictability of arrival & departure times
- Increased flexibility of arrival scheduling
- Increased airport capacity
- Increased safety for terminal area approaches and departures
- Increased efficiency of terminal operations
- Reduced go-arounds
- Enhance special VFR airspace access
- Decreased controller workload
- Decreased voice communications and increased voice-channel availability

App. 3.1 Enhanced Visual Approaches

This application helps pilots visually acquire and identify the aircraft called-out by controllers prior to visual approach clearances by showing the identity and trajectory of aircraft on a CDTI. By using the CDTI to aid in the transition to a visual approach, the procedure will be used more often and more efficiently. Visual approaches are the backbone of operations at major airports in the US and provide greater arrival capacity than IFR operations. During visual approaches, traffic advisories are issued to pilots, and once the pilot confirms acquisition of traffic and runway, a visual approach clearance is issued. Most facilities have specific established minima to which visual approaches can be conducted; however, specific environmental conditions such as haze, sunlight, and patchy clouds may result in the suspension of visual approaches at higher ceiling and visibility values. CDTI may help enhance visual approach operations in one of several ways including:

- Improved visual traffic acquisition
- Reduction in pilot and controller workload
- Increased reliability of conducting visual operations to established minima
- Reduction in the minima to which visual approaches are conducted

The first phase (3.1.1) of the application avoids significant changes to air traffic management (ATM) communication procedures by not including flight ID in traffic call-outs by controllers. This phase also avoids requiring any additional functionality in the ground automation systems by relying solely on the ADS-B of equipped aircraft for the information displayed on the CDTI.

The second phase (3.1.2) of the application extends current pilot/controller procedures for visual approaches to take explicit advantage of the positive identification of traffic that is supported by ADS-B/CDTI. The procedures for traffic call-out by the controller to a CDTI equipped aircraft will be changed to include the flight ID of the traffic. This is expected to further enhance the safety and efficiency of visual approaches.

In the third phase (3.1.3) of the application, non-equipped aircraft appear on the CDTI based on a Traffic Information Service Broadcast (TIS-B) of ground radar-based data. This makes the application more broadly usable in situations of mixed equipage. This phase of the application will address the TIS-B function in the ground automation systems and the human factors issues of presenting TIS-B targets on the CDTI.

App. 3.2 Approach Spacing

This application will provide the pilot with additional cues on the CDTI regarding the dynamics of the aircraft that the pilot is following to improve safety and efficiency.

The first phase (3.2.1) of this application will additional cues on the on visual approach and guidance toward achieving a desired interval. These cues and guidance are expected to allow the pilot to make more consistent and efficient visual approaches.

The second phase (3.2.2) of this application will apply these tools (with extension if needed) for instrument approaches. Spacing near minimum radar separation standards will provide more consistent arrival intervals and higher arrival rates. The pilot will receive radar vectors from ATC to intercept the approach course, and at an appropriate time will be given a spacing interval behind the preceding arrival. At a later time, further enhancements to the CDTI may aid in optimizing protection from wake vortex induced by the lead aircraft.

App. 3.4 Departure Spacing/Clearance

Often minimum spacing is not obtained on departure because of controller workload, pilot response time, and/or limitations of radar surveillance. However, if the CDTI function can aid pilots in departing and maintaining spacing behind a leading aircraft, the controller may be able clear the aircraft for departure based on CDTI spacing and gain additional throughput over the departure routes.

Enhancement 4: Enhanced See and Avoid

This enhancement will provide traffic information, electronically, to the cockpit using ADS-B, CDTI, and TIS-B. This will enable the pilot to maintain situational awareness of surrounding traffic. The expected benefits are the following:

- Increased safety
- Decrease in pilot/controller workload
- Resolve conflicts earlier with resulting efficiencies
- Reduce disruptions to ATC
- Increased capacity
- Increased efficiencies
- Change in tower establishment criteria

App. 4.1 Enhanced Visual Acquisition of Other Traffic for See and Avoid

This application provides a display of nearby traffic on the CDTI to help the pilot see-and-avoid traffic. If traffic is sighted, the pilot must first assess the threat posed by the nearby aircraft then, if necessary, maneuver to avoid the other aircraft. The effectiveness of see-and-avoid depends on the ability of a pilot to visually acquire the nearby aircraft early enough in the encounter to enable threat assessment and avoidance.

The first phase (4.1.1) of this application will be to evaluate see-and-avoid using only ADS-B/CDTI. This will show nearby aircraft that are equipped with ADS-B.

The second phase (4.1.2) of this application extends the CDTI by displaying non-equipped aircraft which are detected by ATC radar and transmitted to the CDTI using TIS-B. In areas with significant numbers of aircraft that are not ADS-B equipped, the effectiveness of using CDTI based on ADS-B only for acquisition of traffic would be limited. With TIS-B information, the identity, position and estimated groundspeed of the other traffic that are known to the controller will be supplied to the pilot. This will assist equipped pilots by providing a display of all nearby traffic within the TIS-B supported area. This phase of the application will address the TIS-B function in the ground automation systems and the human-factors issues of presenting TIS-B targets on the CDTI.

App. 4.2.1 Conflict Detection

This application alerts pilots to potential conflicts with other aircraft, thereby facilitating timely action (if necessary) to prevent or end the conflict. This application will address human factors and algorithm issues such as false alerts, the relationship to TCAS alerts, and indirect impacts on ATC operations.

App. 4.2.2 Conflict Resolution

This application advises the pilot of a maneuver to resolve the previously detected conflict. This application will address human factors and algorithm issues and will address potential interactions with TCAS on one or both aircraft.

Enhancement 5: Enhanced En Route Air-to-Air Operations

This enhancement will evaluate use of CDTI and ADS-B to allow delegation of separation authority to the cockpit, resulting in increased efficiency. The expected benefits are the following:

- Increased en route capacity
- Increased fuel efficiency
- Increased pilot flexibility
- Decreased controller workload
- Increased throughput for “one-in/one-out” airspace

App. 5.2.1 Pilot Situational Awareness Beyond Visual Range

This application extends pilot situational awareness of traffic that is beyond visual range by including distant traffic and airspace boundaries on the cockpit multi-function display. The application is intended to aid pilot-pilot coordination in VFR, SVFR and night operations by showing the overall multiple-aircraft pattern of operations in the airspace rather than only those aircraft that are closest and within visual range. Air-to-air ADS-B messages will identify and give the trajectory of ADS-B equipped aircraft. Ground-to-air TIS-B messages will identify and give the trajectory of non-equipped aircraft that are in radar surveillance. Airspace boundaries will be presented from an on-board database.

Enhancement 6: Improved Surface Surveillance And Navigation For The Pilot

This enhancement will be designed to allow pilots in the cockpit and the operators of equipped vehicles on the airport surface to “see” all the other traffic on a display with a moving map, resulting in safer and more efficient surface operations. Also, aircraft will be able to taxi using augmented GPS navigation and maps and in extremely low visibility conditions using LAAS.

The expected benefits are the following:

- Increased safety during surface movements
- Increased safety during approaches, landings and take-offs
- Reduced taxi times
- Increased predictability of taxi times
- Increased airport capacity (aircraft operations)
- Improved efficiency of gate management operations
- Improved surface operations (all surface operations)
- Improved airport surface operation in IMC conditions
- Reduced surface controller workload

App. 6.1 Runway and Final Approach Occupancy Awareness

This application provides pilots on final approach and on the runway with awareness of other aircraft that are on or approaching the runway.

The initial phase (6.1.1) of this application provides awareness only of equipped aircraft and/or vehicles, and will be of benefit primarily in situations where all or nearly all aircraft/vehicles are equipped. Evaluation will initially be based on the capabilities of un-augmented GPS and basic CDTI, but augmented GPS or limited CDTI enhancements may be found necessary.

The second phase (6.1.2) increases the value of the application by including non-ADS-B-equipped aircraft on the CDTI. The ADS-B data on the CDTI is augmented with TIS-B data from ground-based terminal and surface radar and multilateration techniques. This will provide the pilot of equipped aircraft with information on equipped and non-equipped aircraft, vehicles, and obstructions.

App. 6.2 Airport Surface Situational Awareness

This application enhances the pilot's visual situational awareness by displaying an airport map with aircraft, vehicle, and obstacle positions based on ADS-B (and possibly TIS-B). GPS augmentation with WAAS is expected to be necessary (and adequate) for this application.

Enhancement 7: Enhanced Airport Surface Surveillance For The Controller

This enhancement will equip the aircraft and ground vehicles in the airport movement area with ADS-B using augmented GPS-derived positions. The local and ground controllers in the tower will monitor the position and speeds of all the traffic in the movement area. The expected benefits are the following:

- Increased safety during surface movements
- Increased safety during landings and take-offs

- Reduced taxi times
- Increased predictability of taxi times
- Increased airport capacity (aircraft operations)
- Improved efficiency of gate management operations
- Reduction in emergency response time
- Improved surface operations (all surface operations)
- Reduced rate of pilot/air traffic control communications

App. 7.1 Enhance Existing Surface Surveillance With ADS-B

This application integrates the position, identification, and speed of all equipped ADS-B aircraft with existing surface surveillance to fill the gaps in the existing coverage. The local and ground controllers in the tower could then monitor the position and speeds of all the equipped aircraft.

App. 7.2 Surveillance Coverage at Airports without Existing Surface Surveillance

This application uses ADS-B and multilateration of other radar returns to provide surface surveillance capabilities at airports without existing surface surveillance. This would increase safety monitoring, enhance crash, fire, and rescue capabilities, as well as improve ground ATC operations.

Enhancement 8: ADS-B for Surveillance in Non-Radar Airspace

This enhancement will use ADS-B to provide additional surveillance coverage and fill gaps in today's radar coverage. The expected benefits are the following:

- Increased capacity in airports and airspace
- Reduced separation minima in comparison to procedural separation
- Increased flexibility in route flown
- Increased safety
- Increased efficiency in aircraft operations
- Increased predictability of flight times
- Reduced flight delays

App. 8.1 Center Situational Awareness with ADS-B

This application provides center controllers with enhanced situational awareness of traffic in non-radar airspace by identifying ADS-B equipped aircraft and their trajectories on a controller display. This will aid the controller in providing procedural separation and other non-radar services and in coordinating with the tower controller on airspace changeovers between IFR en route operations and terminal area SVFR operations.

Potential uses of ADS-B to aid search and rescue and for communicating aircraft emergency conditions to the controller are being considered for inclusion in this application.

App. 8.2 Radar-Like Services with ADS-B

This application provides terminal area controllers of non-radar airspace with surveillance, conflict alert and MSAW that are based on ADS-B, to enable provision of radar-like services to VFR and IFR aircraft. This includes emergency services, separation, sequencing, traffic and terrain advisories, navigational assistance, and route optimization. Aircraft not providing ADS-B are handled similarly to aircraft without a transponder in secondary radar airspace.

App. 8.3 Tower Situational Awareness Beyond Visual Range

This application extends the tower cab controller situational awareness of traffic that is beyond visual range by using ADS-B to identify aircraft and their trajectories on a tower display. This application is intended for VFR, SVFR and night operations and will aid tower-pilot and tower-center coordination by showing the over-all multiple-aircraft pattern of operations in the airspace rather than only those aircraft that are nearest the tower and within visual range. In SVFR operations this will also help the tower controller coordinate with the center controller on airspace changeovers between SVFR and IFR operations.

Enhancement 9: Establish ADS-B Separation Standards

Current automation is limited in providing benefits to users based on existing radar accuracy. This enhancement will integrate ADS-B data with radar and conflict alert automation to determine if today's separation standards can be achieved or reduced. Ultimately ADS-B will be integrated with advanced decision support automation. The expected benefits are the following:

- Better controller awareness of equipped traffic actual positions
- Improved ability for radar automation systems to estimate aircraft trajectories (e.g., conflict alert, minimum safe altitude warning)
- Higher surveillance system availability
- More efficient application of separation standards
- More accurate traffic advisories by controller to pilots

App. 9.1.1 Radar Augmentation With ADS-To Support Mixed Equipage In Terminal Airspace

This application integrates ADS-B data with radar data to increase the accuracy and availability of multi-sensor surveillance information in the terminal airspace. Air-to-ground ADS-B messages will contribute to the identification and tracking of ADS-B equipped aircraft when data from multiple sensors is processed for display to the controller. ADS-B will also provide a back up to radar sensors in the event of sensor outage. This application will evaluate the ADS-B accuracy, integrity, and availability for provision of radar-like services as well as the procedures that deal with mixed equipage airspace.

App. 9.2.1 Radar Augmentation With ADS-B To Support Mixed Equipage In En Route Airspace

This application integrates ADS-B data with radar data to increase the accuracy and availability of multi-sensor surveillance information in the en route airspace. Air-to-ground ADS-B messages will contribute to the identification and tracking of ADS-B equipped aircraft when data from multiple sensors is processed for display to the controller. ADS-B will also provide a back up to radar sensors in the event of sensor outage. This application will evaluate the ADS-B accuracy, integrity, and availability for provision of radar-like services as well as the procedures that deal with mixed equipage airspace.

APPENDIX F

BENEFIT OUTCOME METRICS

Draft
Safe Flight 21 Benefit and Output Metrics
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The Safe Flight 21 Cost/Benefit Subgroup developed the benefit metrics by first considering the capabilities provided by each enhancement (column 1 in the attached tables). Then the direct impacts of these capabilities were considered as they directly impact the pilot, controller, or other aspect of flight operations (column 2). Then the output metrics in the following tables present metrics to measure these direct impacts (column 3). This was followed by defining benefit impacts in a descriptive form (column 4) and finally identifying metrics for these benefits outcomes (column 5).

The output metrics in column 3 represent measures that can be measured during the simulations and operational evaluations. The output metrics, with values gathered during the simulations and operational evaluations, are indicators that the benefits in column 5 can be achieved. These output metrics will be further defined during the preparation for the simulations and operational evaluations as the data that can be gathered becomes defined. Some output metrics might be measured through data collection, such as aircraft separation, and others might be measured through pilot observations or surveys, such as time taken by pilot to visually acquire other aircraft after ATC call-out.

The benefit outcome metrics in column 5 will be determined by modeling and estimation. The benefit outcome metrics will also be defined further as the benefit assessment is conducted. For example, the metric, “arrival rate,” might be quantitatively defined as an average and standard deviation over flights during a peak period.

Operational Enhancement # 1: Weather and Other Information to the Cockpit

1.1.1 FIS-B (with NEXRAD, Lightning, METAR/TAF, SIGMET/AIRMET)

Capabilities	Direct Output Impacts	Output Metrics	Benefit Outcome Impacts	Benefit Outcome Metrics

▯ Text and graphic display in cockpit of current weather reports and hazardous weather advisories	▯ Pilot awareness of weather hazards and weather conditions impacting flight planning and flight	▯ Pilot confidence level in equipment during flight segments through airspace with nearby adverse weather conditions
		▯ Unexpected encounter with hazardous weather condition
		▯ Maneuver around weather hazard facilitated by FIS-B information in cockpit
		▯ Pilot request for weather services during an equipped flight through airspace near adverse weather conditions
		▯ Estimated fuel burn during equipped flight compared to average for same route/same aircraft type
		▯ Estimated payload for equipped flight compared to average for same route/same aircraft type
		▯ Pilot flight initiative/cancellation decision significantly impacted by information received via FIS-B
			▯ Reduced flight times by skirting adverse weather
			▯ Increased safety
			▯ Reduced Flight Services workload
			▯ More GA flight initiatives with weather information during flight
			▯ Improvement in tactical planning for aircraft equipped with weather radar
				Safety
				▯ Weather related accident rate
				  ▯ Fatality
				  ▯ Serious injury
				  ▯ Aircraft destruction
				  ▯ Value of aircraft damage
				  ▯ Value of property damage
				  ▯ Accident investigation cost
				▯ Rate of encounters with weather turbulence
				  ▯ Same impacts as above
				
				Savings/Revenue Enhancement
				▯ Number of flight initiatives
				▯ Number of flight diversions
				▯ Number of flight cancellations
				▯ Flight time from take-off to landing
				▯ Difference of planned (i.e., filed in flight plan) versus actual flight time from take-off to landing
				▯ Fuel consumption from take-off to landing
				  ▯ From path flown
				  ▯ From reducing contingency fuel carried
				▯ Insurance premiums
				
				FAA Cost Savings
				▯ Rate of requests for flight services

1.1.2 FIS-B (with Icing, Turbulence, SUA-status, and Volcanic Ash products)

Capabilities	Direct Output Impacts	Output Metrics	Benefit Outcome Impacts	Benefit Outcome Metrics

• Up link to the cockpit of real time, graphic displays of information related to special use airspace status, icing, volcanic ash	• Pilot awareness of projected flight path relative to potential areas of icing and volcanic ash.
	• Pilot awareness of projected flight path relative to special use airspace.
		• Optimum route made available through meteorological/SUA/air route awareness
		• Degree of pilot awareness of projected flight path relative to: icing conditions, Volcanic ash aloft, and Pertinent SUA status
		• Maneuver around icing or volcanic ash facilitated by FIS-B information in cockpit
		• Shorter path flown by pilot through SUA resulting from FIS-B update.
		• Unexpected encounter with icing or volcanic ash
		• Pilot request for weather services during an equipped flight through airspace near adverse weather conditions
		• Pilot flight initiative/cancellation decision significantly impacted by information received via FIS-B
		• Pilot confidence level in weather and SUA information provided via FIS-B
			• Reduced flight times by skirting adverse weather and exploiting available SUA
			• Increased safety
			• Increased access to airspace
			• Reduced Flight Services workload
			• More GA flight initiatives with weather information during flight
			• Improvement in tactical planning for aircraft equipped with weather radar, icing, and SUA graphics
				Safety
				• Weather related accident rate
				  ◦ Fatality
				  ◦ Serious injury
				  ◦ Aircraft destruction
				  ◦ Value of aircraft damage
				  ◦ Value of property damage
				  ◦ Accident investigation cost
				• Rate of encounters with icing or volcanic ash
				  ◦ Same impacts as above
				• Rate of flight encroachments into restricted airspace (precursor)
				
				Savings/Revenue Enhancement
				• Number of flight initiatives
				• Number of flight diversions
				• Number of flight cancellations
				• Flight time from take-off to landing
				• Difference of planned (i.e., filed in flight plan) versus actual flight time from take-off to landing
				• Fuel consumption from take-off to landing
				  ◦ From path flown
				  ◦ From reducing contingency fuel carried
				• Insurance premiums
				
				FAA Cost Savings
				• Rate of requests for flight services

Operational Enhancement # 2: Cost Effective CFIT Avoidance

2.1 Low Cost Terrain Situational Awareness

Capabilities	Direct Output Impacts	Output Metrics	Benefit Outcome Impacts	Benefit Outcome Metrics

• CDTI display to pilots of positions of terrain and obstacles relative to their aircraft based on GPS in combination with an affordable on-board database. Multiple levels of display capability including incorporation of terrain and obstacles.	• Pilot awareness of own position relative to terrain and low altitude obstacles	• Pilot confidence level in equipment during flight segments at low altitudes or near terrain and low altitude obstacles
		
		• Degree of pilot awareness of current position relative to:
		  ◦ terrain
		  ◦ potential obstacles
		
		• Closest in-flight separation distance between equipped aircraft and terrain or surface obstacles
		
		• Time taken by pilot to visually acquire potential surface obstacle
		
		• Shortest lead time for alert to potential ground obstacle during equipped flight
			• Reduced CFIT accidents	Safety
				• Runway/taxiway incursion accident rate
				  ◦ Fatality
				  ◦ Serious injury
				  ◦ Aircraft destruction
				  ◦ Value of aircraft damage
				  ◦ Value of property damage
				  ◦ Accident investigation cost
				• Runway incursion incident rate
				• Taxi clearance deviations
				• Rate of missed approaches (go-around)
				• Rate of aborted landings

2.2 Increased Access to Terrain-Constrained Low Altitude Airspace

Capabilities	Direct Output Impacts	Output Metrics	Benefit Outcome Impacts	Benefit Outcome Metrics
Automated display to pilots and alerting functions based on GPS-navigation and on-board terrain/obstacle databases.	Pilot awareness of projected flight path relative to obstacles and terrain Decreased workload of pilots for maintenance of terrain awareness.	Optimum lower altitude route made available through terrain/air route awareness Degree of pilot awareness of projected flight path relative to: – terrain – potential obstacles Estimated fuel burn during equipped flight compared to average for same route/same aircraft type Estimated payload for equipped flight compared to average for same route/same aircraft type Flight initiative undertaken because of pilot's confidence in CFIT equipage	Decreased pilot workload Increased access to low altitude routes Increased capability to avoid hazardous weather conditions relating to certain altitude (e.g., icing) Increased ability to fly at lower altitude to avoid need for IFR at higher altitude	User Cost Savings/Revenue Enhancement Insurance premiums Volume of usable airspace Flight time from take-off to landing Number of flight initiatives Number of flight cancellations Payload Fuel consumption from take-off to landing

Operational Enhancement # 3: Improved Terminal Operations in Low Visibility

3.1 Enhanced Visual Approaches[1]

Capabilities	Direct Output Impacts	Output Metrics	Benefit Outcome Impacts	Benefit Outcome Metrics

□ Display in cockpit of surrounding traffic & equipment: relative position, ground velocity, ID, and class of aircraft
□ Call out of traffic by ATC to pilots that includes flight ID for positive identification with CDTI
□ Display of acceleration and/or spacing cues for selected aircraft on approach
	□ Pilot able to better identify the aircraft to follow and accomplish VFR approaches at lower minimums
	□ Pilot awareness of all proximate traffic positions
	□ Visual acquisition of all proximate traffic by pilots
	□ Use ADS-B and CDTI to facilitate spacing during approach
	□ Pilot better able to utilize special VFR operations
		□ Pilot confidence level in equipment during approaches in environmental conditions such as haze, sun light, and patchy clouds which can negatively impact VFR (marginal VFR conditions)
		□ Number & duration of ATC communications within terminal area for a specific equipped flight compared to average for all flights during marginal VFR conditions
		□ Separation distance between specific pairs of equipped aircraft during approach in marginal VFR conditions (all flights within same airspace)
		□ Time taken by pilot to visually acquire traffic after ATC call-out (3.1.2 & 3.1.3 only)
		□ Flight time from final approach fix to touchdown compared to average for all flights over same path (same time slot).
		□ Fuel burned during approach compared to average (same approach path)
		□ Number of mis-identifications by pilot in call-backs
		□ Number of repeated traffic call-outs by ATC due to pilot inability to visually acquire traffic
			□ Increased access to airports during marginal VFR environmental conditions
			□ Reduced arrival delays
			□ Increased predictability of arrival times
			□ Increased flexibility of arrival scheduling
			□ Increased airport capacity
			□ Increased safety for terminal area approaches
			□ Increased efficiency of terminal operations
			□ Reduced go-arounds
			□ Enhance special VFR airspace access
			□ Decreased controller workload
			□ Decreased voice communications and increased voice-channel availability
				Safety
				□ Accident rate during final approach maneuvers
				    □ Fatality
				    □ Serious injury
				    □ Aircraft destruction
				    □ Value of aircraft damage
				    □ Value of property damage
				    □ Accident investigation cost
				□ Incident rate during final approach maneuvers
				□ Rate of missed approaches (go-around)
				□ Rate of operational errors in terminal area during final approach maneuvers
				□ Rate of pilot deviations in terminal area during final approach maneuvers
				
				User Cost Savings/Revenue Enhancement
				□ Arrival rate
				□ Flight time in terminal area during final approach maneuvers
				□ Fuel consumption in terminal area during final approach maneuvers
				□ Insurance premiums
				
				FAA Cost Savings
				□ Number of final approaches handled per controller
				□ Voice channel occupancy time during final approaches

[1] Application 3.1 comprises 3 sub-applications: 3.1.1 Enhanced Visual Approaches (Visual Acquisition w/o Positive ID procedures using ADS-B only), 3.1.2 Enhanced Visual Approaches (w/ Positive ID procedures using ADS-B only), and 3.1.3 Enhanced Visual Approaches (w/ Positive ID procedures using ADS-B and TIS-B). These metrics support sub-applications 3.1.1 – 3.1.3.

3.2 Final Approach Spacing

Capabilities	Direct Output Impacts	Output Metrics	Benefit Outcome Impacts	Benefit Outcome Metrics

ADS-B and CDTI cockpit display of aircraft ahead by flight ID, azimuth, distance, and altitude as called by ATC	More rapid verification of the identify of aircraft to follow on final approaches by pilot
	Pilot able to match the speed profile of the lead aircraft based upon displayed proximate positions
	Use of ADS-B/CDTI information to facilitate and maintain optimum spacing during approach
		Pilot response time for verification of lead flight ATC call-out
		Pilot response time for matching the speed profile of leading flight
		Pilot confidence level in relying on equipment for maintaining final approach spacing during low visibility terminal operations
		Flying time during final approach maneuvers compared to terminal average (same conditions and time slot)
		Number and duration of ATC communications within terminal area for a specific equipped flight during final approach compared to average for all flights during low visibility conditions
		Number of mis-identifications by pilot in call-backs
		Number of repeated traffic call-outs by ATC due to pilot inability to visually acquire traffic
		Separation distance between specific pairs of aircraft during approaches in periods meeting low visibility meteorological criteria within terminal area airspace compared to average (all flights within same airspace)
			Increased access to airports during marginal weather
			Reduced arrival delays
			Increased predictability of arrival & departure times
			Increased flexibility of arrival scheduling
			Increased airport capacity
			Increased safety for terminal area approaches
			Increased efficiency of terminal operations
			Reduced go-arounds
			Enhance special VFR airspace access
			Decreased controller workload
			Decreased voice communications and increased voice-channel availability
				Safety
				Accident rate during final approach maneuvers
				    Fatality
				    Serious injury
				    Aircraft destruction
				    Value of aircraft damage
				    Value of property damage
				    Accident investigation cost
				Incident rate during final approach maneuvers
				Rate of missed approaches (go-around)
				Rate of operational errors in terminal area during final approach maneuvers
				Rate of pilot deviations in terminal area during final approach maneuvers
				
				User Cost Savings/Revenue Enhancement
				Arrival rate
				Flight time in terminal area during final approach maneuvers
				Fuel consumption in terminal area during final approach maneuvers
				Insurance premiums
				
				FAA Cost Savings
				Number of final approaches handled per controller
				Voice channel occupancy time during final approaches

3.3 Enhanced Parallel Approaches in VMC/MVMC

Capabilities	Direct Output Impacts	Output Metrics	Benefit Outcome Impacts	Benefit Outcome Metrics

ADS-B and CDTI cockpit display of aircraft ahead and on parallel approaches by flight ID, azimuth, distance, and altitude as called by ATC	• More rapid visual acquisition of preceding landing traffic by pilots
	• Faster visual identification and verification of parallel runway landing traffic by pilots
		• Time taken by pilot to visually acquire lead flight after ATC call-out during parallel approach
		• Time taken by pilot to visually acquire parallel runway traffic after ATC call-out during parallel approach
		• Time taken by pilot to verify lead flight after ATC call-out during parallel approach
		• Time taken by pilot to verify parallel runway traffic per ATC call-out during parallel approach
		• Controller confidence level in use of ADS-B/CDTI equipment by pilots during visual approaches on parallel runways
		• Pilot confidence level in use of ADS-B/CDTI equipment by pilots during visual approaches on parallel runways
		• Aircraft separation between specific pairs of aircraft during parallel landings compared to average separation
		• Number of traffic call-outs during parallel landing compared with average per landing (same time slot & conditions)
			• Increased access to airports during parallel landing operations
			• Reduced arrival delays
			• Increased predictability of arrival times
			• Increased flexibility of arrival scheduling
			• Increased airport capacity
			• Increased safety for terminal area approaches
			• Increased efficiency of terminal operations
			• Reduced go-arounds
			• Decreased controller workload during parallel landings
				Safety
				• Accident rate during parallel landings
				    ◦ Fatality
				    ◦ Serious injury
				    ◦ Aircraft destruction
				    ◦ Value of aircraft damage
				    ◦ Value of property damage
				    ◦ Accident investigation cost
				• Incident rate during parallel landings
				• Rate of missed approaches (go-around) during parallel landings
				• Rate of operational errors in terminal area during parallel landings
				• Rate of pilot deviations in terminal area during parallel landings
				
				User Cost Savings/Revenue Enhancement
				• Arrival rate
				• Flight time in terminal area
				• Fuel consumption in terminal area
				• Insurance premiums
				
				FAA Cost Savings
				• Number flights handled per controller
				• Voice channel occupancy time

3.4 Departure Spacing (VMC)

Capabilities	Direct Output Impacts	Output Metrics	Benefit Outcome Impacts	Benefit Outcome Metrics

• ADS-B and CDTI cockpit display of aircraft ahead by flight ID, azimuth, distance, and altitude as called by ATC	• Pilot able to more rapidly verify the identify of aircraft to follow on departures
	• Pilot able to match the speed profile of the lead aircraft based upon displayed proximate positions
	• Use ADS-B/CDTI information to facilitate and maintain optimum spacing during departures
		• Time taken by pilot to visually acquire lead flight after ATC call-out
		• Time taken by pilot to verify lead flight after ATC call-out
		• Time taken by pilot to match the speed profile of leading flight
		• Pilot confidence level in relying on equipment for maintaining departure spacing during low visibility terminal operations
		• Number and duration of ATC communications within terminal area for a specific equipped flight compared to mean communications for all flights during low visibility conditions;
		• Aircraft separation distance between specific pairs of aircraft during departures in periods meeting low visibility meteorological criteria within terminal area airspace compared to average separation distance (all flights within same airspace)
			• Increased access to airports during marginal weather
			• Increased predictability of departure times
			• Increased flexibility of arrival scheduling
			• Increased airport capacity
			• Increased safety for terminal area departures
			• Increased efficiency of terminal operations
			• Enhance special VFR airspace access
			• Decreased controller workload
			• Decreased voice communications and increased voice-channel availability
				Safety
				• Accident rate during takeoffs and departures
				  ◦ Fatality
				  ◦ Serious injury
				  ◦ Aircraft destruction
				  ◦ Value of aircraft damage
				  ◦ Value of property damage
				  ◦ Accident investigation cost
				• Incident rate during takeoffs and departures
				• Rate of operational errors in terminal area during takeoffs and departures
				• Rate of pilot deviations in terminal area during takeoffs and departures
				
				User Cost Savings/Revenue Enhancement
				• Departure rate
				• Flight time in terminal area during takeoffs and departures
				• Fuel consumption in terminal area during takeoffs and departures
				• Insurance premiums
				
				FAA Cost Savings
				• Number of takeoffs handled per controller
				• Voice channel occupancy time during takeoffs and departures

Operational Enhancement # 4: Enhanced See and Avoid (ESA)

4.1 Enhanced Visual Acquisition of Other Traffic for See and Avoid[2]

Capabilities	Direct Output Impacts	Output Metrics	Benefit Outcome Impacts	Benefit Outcome Metrics

• Display position of surrounding equipped traffic in cockpit relative to aircraft's own position	• Increase pilot awareness of all proximate equipped traffic positions
	• Increase visual acquisition of all proximate equipped traffic by pilots
		• Pilot visual acquisition response time for proximate equipped traffic
		• Closing speed & distance from target at time of visual acquisition
		• Pilot confidence level in relying on equipment to support see and avoid procedures
		• Degree of pilot awareness of: own position vis a vis equipped proximate local traffic
			• Increased safety	Safety
				• Mid-air collision rate
				    • Fatality
				    • Serious injury
				    • Aircraft destruction
				    • Value of aircraft damage
				    • Value of property damage
				    • Accident investigation cost
				• Response time for pilot's visual acquisition of target
				• Near mid-air collision rate

[2] Application 4.1 comprises 2 sub-applications: 4.1.2 Enhanced Visual Acquisition of Other Traffic for See and Avoid (using ADS-B only) and 4.1.2 Enhanced Visual Acquisition of Other Traffic for See and Avoid (using ADS-B and TIS-B). These metrics support both 4.1.1 & 4.1.2.

4.2 Traffic Situational Awareness in Domestic Airspace

Capabilities	Direct Output Impacts	Output Metrics	Benefit Outcome Impacts	Benefit Outcome Metrics

• Display position of surrounding equipped traffic in cockpit relative to aircraft's own position	• Increase pilot awareness of all proximate equipped traffic positions
	
	• Increase visual acquisition of all proximate equipped traffic by pilots
		• Degree of pilot awareness of: own position vis-a-vis equipped proximate local traffic and contextual attributes of the airspace domain (i.e. in approach airspace, awareness of airport configuration vis-a-vis arriving and departing traffic)
		
		• Pilot confidence level in relying on equipment to support traffic situational awareness
			• Increased safety	• Mid-air collision rate
				  ◦ Fatality
				  ◦ Serious injury
				  ◦ Aircraft destruction
				  ◦ Value of aircraft damage
				  ◦ Value of property damage
				  ◦ Accident investigation cost
				• Near mid-air collision rate

4.3 Conflict Situational Awareness[3]

Capabilities	Direct Output Impacts	Output Metrics	Benefit Outcome Impacts	Benefit Outcome Metrics
• CDTI with TIS-B information including strategic traffic alerts (TA) to warn pilots of potential conflicts. Resolution Advisories (RA) enable coordinated action to avoid conflict.	• Warning of potential mid-air conflicts • Advise on resolving conflicts • Ability for pilots to coordinate with ATC prior to conflict avoidance maneuvers • Reduced magnitude of course changes for conflict avoidance and/or resolution • Reduce resolution advisories with corresponding reduced disruption to ATC	• Air traffic control conflict advisories and directives for a specific equipped flight in comparison to mean for all flights within same airspace over historical baseline period • Deviation in total mileage flown during a flight's deconfliction maneuvers compared to "estimated optimal deconfliction paths" • Fuel burned during flight deconfliction maneuvers versus estimated fuel burn for optimum deconfliction maneuvers • Number of False alerts during equipped flight • Pilot confidence level in use of ADS-B/CDTI traffic alerts and resolution advisories • Controller confidence level in use of ADS-B/CDTI equipment by pilots during conflict resolution procedures	• Increased safety • Decrease in pilot/controller workload • Resolve conflicts earlier with resulting efficiencies • Reduce disruptions to ATC • Increased capacity • Increased efficiencies • Change in tower establishment criteria	Safety • Mid air accident rate – Fatality – Serious injury – Aircraft destruction – Value of aircraft damage – Value of property damage – Accident investigation cost • Mid air incident rate • Rate of operational errors in domestic airspace • Rate of pilot deviations in domestic airspace User Cost Savings/Revenue Enhancement • Arrival rate • Flight time in terminal area • Fuel consumption in terminal area • Insurance premiums FAA Cost Savings • Number flights handled per controller • Voice channel occupancy time

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3 Application 4.3 comprises two sub-applications: 4.3.1 Conflict Situational Awareness and 4.3.2 Flight-Path Deconfliction. These metrics support both 4.3.1 & 4.3.2.

Operational Enhancement # 5: Enhanced En Route Air-to-Air Operations

5.1 Closer Climb & Descent in Non-Radar Airspace

Capabilities	Direct Output Impacts	Output Metrics	Benefit Outcome Impacts	Benefit Outcome Metrics
Cockpit display (CDTI based on ADS-B) of positions of other equipped aircraft in en route airspace	Pilot awareness of all proximate traffic positions within flight level through which he or she intends to climb or descend in non-radar airspace Enhanced climb and descend procedures by ADS-B equipped aircraft in en-route airspace	Pilot confidence level in equipment during climb or descent maneuvers in non-radar airspace Separation distance between specific pairs of equipped aircraft during climb or descent maneuvers in Non-Radar Airspace Pilot preferred route initiative made possible by CDTI/ADS-B equipment Estimated fuel or time savings by flying optimum speed and path during climb and descend maneuvers	Increased flexibility in routes flown Increased en route capacity Increased predictability of flight times & distance flown Reduction in flight delays and distances flown Increased fuel efficiency Increased pilot flexibility Increased controller productivity Increased access to non-radar airspace	User Cost Savings/Revenue Enhancement Flight time (en route) Fuel consumption (en route) Number aircraft per sector or position per unit time Time spent at or near desired altitude (en route) FAA Cost Savings Number of flights handled per controller (en route airspace)

5.2 Extended See and Avoid

Capabilities	Direct Output Impacts	Output Metrics	Benefit Outcome Impacts	Benefit Outcome Metrics
Cockpit display (CDTI based on ADS-B) of positions of other equipped aircraft in non-radar airspace	Pilot awareness of all proximate traffic positions in non-radar airspace Increased flexibility for station keeping maneuvers by ADS-B equipped aircraft in non-radar airspace	Pilot confidence level in equipment during station keeping maneuvers Average separation distance between specific pairs of equipped aircraft during a specific set of station keeping maneuvers in non radar airspace Number and duration of ATC callouts to specific pair of equipped flights during a specific set of station keeping maneuvers in non radar airspace	Increased en route capacity Increased fuel efficiency Increased pilot flexibility Decreased controller productivity Decreased controller productivity Increased throughput for “one-in/one-out” airspace	User Cost Savings/Revenue Enhancement Flight time (en route) Fuel consumption (en route) Number aircraft per sector or position per unit time Time spent at or near desired altitude (en route) FAA Cost Savings Number of flights handled per controller (en route airspace)

5.3 In-Trail Spacing in En Route Airspace

Capabilities	Direct Output Impacts	Output Metrics	Benefit Outcome Impacts	Benefit Outcome Metrics
Cockpit display (CDTI based on ADS-B) of positions of other equipped aircraft in en route airspace	Pilot awareness of all proximate traffic positions in en route airspace Increased flexibility for in-trail spacing maneuvers by ADS-B equipped aircraft in en route airspace Delegation of spacing responsibility for station keeping in non radar airspace to pilots by service providers	Pilot confidence level in equipment during establishment of in trail spacing maneuvers Time taken for ATC specified in trail separation distance to be established by following aircraft after ATC callout (between specific pairs of equipped aircraft) in en route airspace Number and duration of ATC callouts to following aircraft during in trail spacing maneuvers for specific pair of equipped flights in en route airspace	Increased fuel efficiency Increased pilot flexibility Increased controller productivity Increased en route capacity	User Cost Savings/Revenue Enhancement Fuel consumption (en route) Number aircraft per sector or position per unit time Time spent at or near desired altitude and speed (en route) FAA Cost Savings Number of flights handled per controller (en route airspace)

5.4 Merging in En Route Airspace

Capabilities	Direct Output Impacts	Output Metrics	Benefit Outcome Impacts	Benefit Outcome Metrics
□ Cockpit display (CDTI based on ADS-B) of positions of other equipped aircraft in en route airspace	□ Pilot awareness of all proximate traffic positions within flight level through which he or she intends to climb or descend in non-radar airspace □ Enhanced climb and descend procedures by ADS-B equipped aircraft in en-route airspace □ Enhanced merging by ADS-B equipped aircraft in en route airspace □ More efficient passing maneuvers by ADS-B equipped aircraft in en route airspace	□ Pilot confidence level in equipment during merging maneuvers in en route airspace □ Separation distance between specific pairs of equipped aircraft during merging maneuvers in en route airspace □ Estimated fuel or time savings by flying preferred maneuvers during merging	□ Increased pilot flexibility □ Increased controller productivity □ Increased fuel efficiency	User Cost Savings/Revenue Enhancement □ Flight time (en route) □ Fuel consumption (en route) □ Number aircraft per sector or position per unit time □ Time spent at or near desired altitude (en route) FAA Cost Savings □ Number of flights handled per controller (en route airspace)

5.5 Passing Maneuvers in En Route Airspace

Capabilities	Direct Output Impacts	Output Metrics	Benefit Outcome Impacts	Benefit Outcome Metrics
Cockpit display (CDTI based on ADS-B) of positions of other equipped aircraft in en route airspace	Pilot awareness of all proximate traffic positions within flight level through which he or she intends to climb or descend or pass laterally in en route airspace More efficient passing maneuvers by ADS-B equipped aircraft in en route airspace	Pilot confidence level in equipment during passing maneuvers in en route airspace Separation distance between specific pairs of equipped aircraft during passing maneuvers in en route airspace Pilot preferred passing initiative made possible by CDTI/ADS-B equipment Estimated fuel or time savings by flying preferred passing maneuvers by equipped flight	Increased flexibility in routes flown Increased en route capacity Increased predictability of flight times & distance flown Reduction in flight delays and distances flown Increased fuel efficiency Increased pilot flexibility	User Cost Savings/Revenue Enhancement Flight time (en route) Fuel consumption (en route) Time spent at or near desired altitude (en route)

Operational Enhancement # 6: Improved Surface Navigation for the Pilot

6.1.1 Runway and Final Approach Occupancy Awareness (using ADS-B only)

Capabilities	Direct Output Impacts	Output Metrics	Benefit Outcome Impacts	Benefit Outcome Metrics
- Cockpit display (CDTI based on ADS-B) of positions of other equipped aircraft that are on or approaching the runway relative to own position (below 1000 ft elevation)	- Pilot awareness of own position relative to equipped local air traffic at altitudes less than 1000 ft - Pilot awareness of own position relative to equipped aircraft on airport surface	- Pilot confidence level in equipment during final approach, landing, and taxi - Degree of pilot awareness of own position during final approach relative to: – runway/ taxiway/ gate configurations; – local air traffic at altitudes less than 1000 feet; – obstacles - Number & duration of ATC communications within terminal area for a specific equipped flight during final approach, landing, and taxi compared to average for all flights (same path & time slot) - Closest separation distance between specific pairs of equipped aircraft during final approach, landing, and taxi - Taxi time from touchdown to gate for equipped flight compared to average for all flights over same taxi path (same time slot).	- Increased safety during surface movements - Increased safety during landings - Reduced taxi times - Increased predictability of taxi times - Increased airport capacity (aircraft operations) - Improved efficiency of gate management operations - Improved surface operations (all surface operations) - Improved airport surface operation in CAT-3 conditions - Reduced surface controller workload	Safety - Runway/taxiway incursion accident rate – Fatality – Serious injury – Aircraft destruction – Value of aircraft damage – Value of property damage – Accident investigation cost - Runway incursion incident rate - Taxi clearance deviations - Rate of aborted landings User Cost Savings/Revenue Enhancement - Taxi time from touchdown to gate - Arrival rate - Departure rate - nsurance premiums FAA Cost Savings - Number aircraft and vehicles handled per surface controller - Voice channel occupancy time - Number of surface controller transmissions per aircraft

6.1.2 Runway and Final Approach Occupancy Awareness (using ADS-B and TIS-B)

Capabilities	Direct Output Impacts	Output Metrics	Benefit Outcome Impacts	Benefit Outcome Metrics
Cockpit display (CDTI based on ADS-B & TIS-B) of positions of other aircraft that are on or approaching the runway relative to own position (below 1000 ft elevation)	Pilot awareness of own position relative to other local aircraft at altitudes less than 1000 ft Pilot awareness of own position relative to aircraft on runways	Pilot confidence level in equipment during final approaches, landings, and taxi Degree of pilot awareness of own position during final approach relative to: – Runway/ taxiway/ gate configurations; – Local air traffic at altitudes less than 1000 feet; – Obstacles Number & duration of ATC communications within terminal area during final approach, landing, and taxi for a specific equipped flight compared to average for all flights Closest separation distance between equipped aircraft and all other aircraft in terminal area during final approach and landings Taxi time from touchdown to gate for equipped flight compared to average for all flights over same taxi path (same time slot).	Increased safety during surface movements Increased safety during landings Reduced taxi times Increased predictability of taxi times Increased airport capacity (aircraft operations) Improved efficiency of gate management operations Improved surface operations (all surface operations) Improved airport surface operation in CAT-3 conditions Reduced surface controller workload	Safety Runway/taxiway incursion accident rate – Fatality – Serious injury – Aircraft destruction – Value of aircraft damage – Value of property damage – Accident investigation cost Runway incursion incident rate Taxi clearance deviations Rate of aborted landings User Cost Savings/Revenue Enhancement Taxi time from touchdown to gate Arrival rate Departure rate Insurance premiums FAA Cost Savings Number aircraft and vehicles handled per surface controller Voice channel occupancy time Number of surface controller transmissions per aircraft

6.2 Airport Surface Situational Awareness

Capabilities	Direct Output Impacts	Output Metrics	Benefit Outcome Impacts	Benefit Outcome Metrics
CDTI display of positions of own aircraft relative to other aircraft, vehicles, and obstacles around the airport surface (based on ADS-B and possibly TIS-B). Cockpit display includes an overlay map of the airport.	Pilot awareness of own position relative to runway/ taxiway/ gate configurations, and obstacles Pilot awareness of own position relative to local air traffic at altitudes less than 1000 ft traffic Pilot awareness of own position relative to airport surface vehicles and aircraft	Pilot confidence level in equipment during final approaches, landings, and taxi Degree of pilot awareness of own position during final approach relative to: – runway/ taxiway/ gate configurations; – local air traffic at altitudes less than 1000 feet; – obstacles – surface vehicles and traffic Number & duration of ATC communications within terminal area during final approach, for a specific equipped flight compared to average for all flights Closest separation distance between equipped aircraft and all other aircraft in terminal area during final approach	Increased safety during final approach and landing Increased airport capacity (aircraft operations) Reduced surface controller workload	Safety Runway/taxiway incursion accident rate – Fatality – Serious injury – Aircraft destruction – Value of aircraft damage – Value of property damage – Accident investigation cost Runway incursion incident rate Taxi clearance deviations Rate of missed approaches (go-around) Rate of aborted landings User Cost Savings/Revenue Enhancement Arrival rate Departure rate Insurance premiums FAA Cost Savings Number aircraft handled per controller during approaches Voice channel occupancy time Number of controller transmissions per aircraft approach

6.3 Enhanced IMC Airport Surface Operations

<table>
<tr><th>Capabilities</th><th>Direct Output Impacts</th><th>Output Metrics</th><th>Benefit Outcome Impacts</th><th>Benefit Outcome Metrics</th></tr>
<tr>
<td>- IMC surface navigation via CDTI display of positions of own aircraft relative to other aircraft, vehicles, obstacles, and the airport surface (based on on-board databases, ADS-B, and possibly TIS-B).</td>
<td>- Pilot awareness of own position relative to runway/ taxiway/ gate configurations, and obstacles while taxing during IMC
- Pilot awareness of own position relative to surface vehicles and other local aircraft while taxing during IMC</td>
<td>- Pilot confidence level in equipment during final approaches, landings, and taxi during IMC
- Degree of pilot awareness of own position during taxi in IMC relative to:
  – runway/ taxiway/ gate configurations;
  – local air traffic at altitudes less than 1000 feet;
  – obstacles
- Number & duration of ATC communications within terminal area during taxi for a specific equipped flight during IMC compared to average for all flights during IMC (same time slot).
- Closest separation distance between equipped aircraft and all other aircraft in terminal area during taxi in IMC
- Taxi time from pushback to takeoff for equipped flight in IMC compared to average for all flights over same taxi path during IMC (same time slot)
- Taxi time from touchdown to gate for equipped flight in IMC compared to average for all flights over same taxi path during IMC (same time slot).</td>
<td>- Increased safety during surface movements
- Increased safety during landings and take-offs
- Reduced taxi times
- Increased predictability of taxi times
- Increased airport capacity (aircraft operations)
- Improved efficiency of gate management operations
- Improved surface operations (all surface operations)
- Improved airport surface operation in CAT-3 conditions
- Reduced surface controller workload</td>
<td>Safety
- Runway/taxiway incursion accident rate
  – Fatality
  – Serious injury
  – Aircraft destruction
  – Value of aircraft damage
  – Value of property damage
  – Accident investigation cost
- Runway incursion incident rate
- Taxi clearance deviations

User Cost Savings/Revenue Enhancement
- Taxi time from touchdown to gate
- Arrival rate
- Departure rate
- Taxi time from pushback to takeoff
- Insurance premiums

FAA Cost Savings
- Number aircraft and vehicles handled per surface controller
- Voice channel occupancy time
- Number of surface controller transmissions per aircraft</td>
</tr>
</table>

Operational Enhancement # 7: Enhanced Surface Surveillance for the Controller

7.1 Enhanced Presentation of Surface Targets to Controller (at airports with ASDE)

Capabilities	Direct Output Impacts	Output Metrics	Benefit Outcome Impacts	Benefit Outcome Metrics
• Display to tower controllers of position, identification, and speed of all aircraft on surface and ground vehicles in the airport movement area	• Tower controller awareness of all proximate surface traffic positions, speeds and headings	• Controller confidence level in equipment during surface movement operations • Number & duration of ATC communications within terminal area for a specific equipped flight during ground operations compared to average for all flights over same path (same time slot) • Minimum separation distance between a specific equipped aircraft and other aircraft, vehicles or obstacles during taxi • Taxi time from touchdown to gate or gate to wheels-up for specific equipped flight compared to average for all flights over same path (same time slot). • Number of repeated traffic call-outs by local or ground control due to pilot inability to visually acquire surface obstacle or traffic	• Increased safety for terminal surface areas • Reduction in taxi times • Increased predictability of taxi times • Increased airport capacity (aircraft operations) • Reduction in emergency response time • Improved surface operations (all surface operations) • Reduced rate of pilot/air traffic control communications	Safety • Taxiway accident rate – Fatality – Serious injury – Aircraft destruction – Value of aircraft damage – Value of property damage – Accident investigation cost • Taxiway incidents rate • Runway incursion accident rate – Fatality – Serious injury – Aircraft destruction – Value of aircraft damage – Value of property damage – Accident investigation cost • Emergency response time User Cost Savings/Revenue Enhancement • Taxi time from touchdown to gate • Taxi time from pushback to takeoff • Departure rate • Arrival rate • Insurance premiums FAA Cost Savings • Voice channel occupancy time • Avoided costs for establishing new surface traffic surveillance

7.2 Surveillance Coverage at Airports without ASDE

Capabilities	Direct Output Impacts	Output Metrics	Benefit Outcome Impacts	Benefit Outcome Metrics

• Display to tower controllers at Airports without ASDE of position, identification, and speed of all aircraft on surface and ground vehicles in the airport movement area	• Tower controller awareness of all proximate surface traffic positions, speeds and headings
	
	• Cost effective means of implementing ASDE-like capabilities at airports without ASDE and thereby increase safety monitoring, enhance crash, fire, and rescue capabilities, as well as improve ground ATC.
		• Controller confidence level in equipment during surface movement operations in low visibility conditions
		
		• Number & duration of ATC communications within terminal area for a specific equipped flight during ground operations in low visibility conditions compared to average for all flights over same path (same time slot)
		
		• Minimum separation distance between a specific equipped aircraft and other aircraft, vehicles or obstacles during taxi in low visibility conditions
		
		• Taxi time from touchdown to gate or gate to wheels-up for specific equipped flight in low visibility conditions compared to average for all flights over same path (same time slot).
		
		• Number of repeated traffic call-outs by local or ground control due to pilot inability to visually acquire surface obstacle or traffic during low visibility conditions
			• Increased safety during surface movements
			
			• Increased safety during landings and take-offs
			
			• Reduced taxi times
			
			• Increased predictability of taxi times
			
			• Increased airport capacity (aircraft operations)
			
			• Improved efficiency of gate management operations
			
			• Improved airport surface operation in CAT-3 conditions
				Safety
				• Taxiway accident rate
				  ◦ Fatality
				  ◦ Serious injury
				  ◦ Aircraft destruction
				  ◦ Value of aircraft damage
				  ◦ Value of property damage
				  ◦ Accident investigation cost
				
				• Taxiway incidents rate
				
				• Runway incursion accident rate
				  ◦ Fatality
				  ◦ Serious injury
				  ◦ Aircraft destruction
				  ◦ Value of aircraft damage
				  ◦ Value of property damage
				  ◦ Accident investigation cost
				
				• Emergency response time
				
				User Cost Savings/Revenue Enhancement
				• Taxi time from touchdown to gate
				• Taxi time from pushback to takeoff
				• Departure rate
				• Arrival rate
				• Insurance premiums
				
				FAA Cost Savings
				• Voice channel occupancy time
				• Avoided costs for establishing new surface traffic surveillance

Operational Enhancement # 8: ADS-B for Surveillance in Non-Radar Airspace

8.1 Expanded Surveillance Coverage in En Route Non-Radar Airspace

Capabilities	Direct Output Impacts	Output Metrics	Benefit Outcome Impacts	Benefit Outcome Metrics
Use of ADS-B to provide additional surveillance coverage and fill gaps in radar. Provides this information to ATC service providers	En route Traffic surveillance outside of radar coverage	Pilot confidence level in relying on equipment to support en route surveillance coverage ATC provider confidence level in relying on equipment to support en route surveillance coverage Degree of pilot awareness of: own position vis a vis equipped proximate en route traffic Degree of ATC provider awareness of position of all equipped sector en route traffic Aircraft separation between specific pairs of aircraft during in trail en route flight segments compared to established radar separation standards	Increased capacity in airports and airspace – Reduced separation minima in comparison to procedural separation Increased flexibility in route flown Increased safety Increased efficiency in aircraft operations Increased predictability of flight times Reduced flight delays	Safety Accident rate in non-radar airspace - Fatality - Serious injury - Aircraft destruction - Value of aircraft damage - Value of property damage - Accident investigation cost Incident rate in non-radar airspace Rate of operational errors and pilot deviations User Cost Savings/Revenue Enhancement Number of aircraft in non-radar airspace per unit time Flight time Fuel consumption in non-radar airspace Number of diversions Arrival rate at non-radar airports Departure rate at non-radar airports Time spent at or near desired altitude Insurance premiums Avoided costs of establishing radar facilities FAA Cost Savings Avoided costs of establishing radar facilities

8.2 Expanded Surveillance Coverage in Terminal Areas without Radar

Capabilities	Direct Output Impacts	Output Metrics	Benefit Outcome Impacts	Benefit Outcome Metrics
□ Use of ADS-B to provide additional surveillance coverage within non-radar terminal areas. Provides this information to ATC service providers	□ Air traffic surveillance within terminal area at non-radar airports	□ Pilot confidence level in relying on equipment to support terminal area surveillance coverage at non-radar airports □ ATC provider confidence level in relying on equipment to support terminal area surveillance coverage at non-radar airports □ Degree of pilot awareness of: own position vis a vis equipped proximate terminal area traffic □ Degree of ATC provider awareness of position of all equipped terminal area traffic □ Aircraft separation between specific pairs of aircraft within the terminal area compared to established radar separation standards.	□ Increased capacity in airports and airspace – Reduced separation minima in comparison to procedural separation □ Increased flexibility in route flown □ Increased safety □ Increased efficiency in aircraft operations □ Increased predictability of flight times □ Reduced flight delays	Safety □ Accident rate in non-radar airspace □ Fatality □ Serious injury □ Aircraft destruction □ Value of aircraft damage □ Value of property damage □ Accident investigation cost □ Incident rate in non-radar airspace □ Rate of operational errors and pilot deviations User Cost Savings/Revenue Enhancement □ Number of aircraft in non-radar airspace per unit time □ Flight time □ Fuel consumption in non-radar airspace □ Number of diversions □ Arrival rate at non-radar airports □ Departure rate at non-radar airports □ Time spent at or near desired altitude □ Insurance premiums □ Avoided costs of establishing radar facilities FAA Cost Savings □ Avoided costs of establishing radar facilities

Operational Enhancement # 9: ADS-B Separation Standards

9.1 ADS-B Enhancement of En Route Radar

Capabilities	Direct Output Impacts	Output Metrics	Benefit Outcome Impacts	Benefit Outcome Metrics
More accurate aircraft position and velocity information, and more frequent updates presented to controller (en route)	Better controller awareness of equipped traffic actual positions Improved ability for radar automation systems to estimate aircraft trajectories (e.g., conflict alert, minimum safe altitude warning) Higher surveillance system availability More efficient application of separation standards More accurate traffic advisories by controller to pilots	Controller confidence level in relying on equipment to support flight segments in en route airspace Degree of sector controller awareness of position of equipped flight vis a vis all proximate en route traffic Average separation distance of specific equipped flight during en route flight segment resulting from ATC advisories	Better controller awareness of equipped traffic actual positions Improved ability for radar automation systems to estimate aircraft trajectories (e.g., conflict alert, minimum safe altitude warning) Higher surveillance system availability More efficient application of separation standards More accurate traffic advisories by controller to pilots	Safety Accident rate Fatality Serious injury Aircraft destruction Value of aircraft damage Value of property damage Accident investigation cost Incident rate Rate of operational errors User Cost Savings/Revenue Enhancement Arrival rate Departure rate Flight time in terminal area Fuel consumption Insurance premiums FAA Cost Savings Voice channel occupancy time Spectrum available Controller workload

9.2 ADS-B Enhancement of Terminal Radar

Capabilities	Direct Output Impacts	Output Metrics	Benefit Outcome Impacts	Benefit Outcome Metrics

• More accurate aircraft position and velocity information, and more frequent updates presented to terminal controller	• Better terminal controller awareness of equipped traffic actual positions
	• Improved ability for radar automation systems to estimate aircraft trajectories (e.g., conflict alert, minimum safe altitude warning) in terminal area
	• Higher surveillance system availability in terminal area
	• More efficient application of separation standards in terminal area
	• More accurate traffic advisories by controller to pilots in terminal area
		• Controller confidence level in relying on equipment to support maneuvers in terminal area
		• Degree of controller awareness of position of equipped flight vis a vis all proximate terminal area traffic
		• Average separation distance of specific equipped flight during terminal area maneuvers resulting from ATC advisories
			• Better controller awareness of equipped traffic actual positions
			• Improved ability for radar automation systems to estimate aircraft trajectories (e.g., conflict alert, minimum safe altitude warning)
			• Higher surveillance system availability
			• More efficient application of separation standards
			• More accurate traffic advisories by controller to pilots
				Safety
				• Accident rate
				  ◦ Fatality
				  ◦ Serious injury
				  ◦ Aircraft destruction
				  ◦ Value of aircraft damage
				  ◦ Value of property damage
				  ◦ Accident investigation cost
				• Incident rate
				• Rate of operational errors
				
				User Cost Savings/Revenue Enhancement
				• Arrival rate
				• Departure rate
				• Flight time in terminal area
				• Fuel consumption
				• Insurance premiums
				
				FAA Cost Savings
				• Voice channel occupancy time
				  ◦ Spectrum available
				• Controller workload

APPENDIX G

MODELS AND TOOLS

Models:

NAS queuing model developed by ASD-430.

Simplified queuing model from Lincoln Labs.

Tools:

Analytica: Common data sets, relationship trees, sensitivity analysis.

Data Sources:

Sources of information included the discussions and information provided by the following:

- Larry Lichtenberg at UPSAT – 503-391-3440
- Leonark Kirk at the University of Alaska – 907-264-7436
- Gary Childers and James Call from the FAA Alaska Region – 907-271-6304
- Ellis Macelroy from the Capstone Project – Ellis.mcelroy@faa.gov
- Warren Randolf and Michelle Wooten supporting the NASDAC office – 202-493-4247
- Paul Feducia, head of the Weather JSAT

For the FIS-B enhancement, we relied on the following data sources:

- The NTSB Weather study of the CONUS, 1987-1998
- The NTSB Weather study generated for Alaska only 1987 –19988 (by Michelle Wooten)
- The 1998 NALL report
- TAF data on the number of flight operations per year by aircraft class
- NIOSH report – National Institute of Occupational Safety and Health
- VMC to IMC study done by Oklahoma City
- Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs (June 1998)

For the CFIT enhancement, we relied on the following data sources:

- NTSB
  - U.S. Commercial Operator CFIT Accidents 1988 through 1994
  - Publications with CFIT in the title
  - Relevant NTSB occurrence codes
  - *An Analysis of Controlled-Flight-Into-Terrain (CFIT) Accidents of Commercial Operations 1988 through 1994*, Flight Safety Digest, Flight Safety Foundation; April-May 1996
  - Volpe Study: General Aviation CFIT Accidents 1983 through 1994
  - *Investigation of Controlled Flight Into Terrain*:
  - *Aircraft Accidents Involving Turbine-Powered Aircraft with Six or More Passenger Sets Flying Under FAR Part 91 Flight Rules and the Potential for Their Prevention by Ground Proximity Warning Systems* (GPWS), U.S. Department of Transportation, DOT-TST-FA6D1-96-01; March 1996.
  - *For Selected Aircraft Accidents Involving Aircraft Flying UnderPart121 and 1351 Flight Rules and the Potential for Their Prevention by Enhanced Ground Proximity Warning Systems* (EGPWS), U.S. Department of Transportation, DOT-TSC-FA6D1-96-03; July 1996.
  - *Descriptions of Flight Paths for Selected Controlled Flight into Terrain (CFIT) Aircraft Accidents, 1985-1997*, U.S. Department of Transportation, DOT-TSC-FA9D1-99-01; March 1999.
  - TAF data on the number of flight operations per year by aircraft class
  - Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs (June 1998).